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NICAM 728:

Factors affecting the assessment of UHF transmitter linearity

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Summary

Work has been carried out to investigate the need for change in the specification of transmitter distortion levels once the digital stereo sound carrier has been introduced. New test signals have been proposed and subjective tests have been conducted to determine the visibility of the original distortion products and, hence, to determine appropriate limits.

Index terms: *TV transmitters; TV broadcasting; digital audio signals; compatibility; subjective tests; intermodulation; test signals; linearity*

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1. INTRODUCTION

The BBC has developed a new system which will allow stereophonic sound to be broadcast on the existing UHF television network. An additional stereo sound signal, on a digitally modulated carrier, is placed 0.552 MHz above the existing sound carrier frequency[1].

In order to ensure that the new multiplex signal is compatible with existing receivers and that the CCIR guidelines on interference are met, the level of the main sound carrier is reduced from 7 dB to 10 dB below the peak power of the vision carrier (−10 dBp). The level of the digital sound carrier is set at −20 dBp.

One advantage of the new multiplex is that it can be transmitted with minimal change in transmitter configuration. At stations where separate sound and vision amplifiers are used, the two sound signals would share the same amplifier. At relay stations, the whole multiplex signal is usually amplified in one common amplifier. It is unlikely that this practice would need to be changed substantially.

The addition of the digital signal does, however, impose more stringent requirements on system linearity. At relay stations, the output power is limited by the onset of distortion. In particular, the beat between the vision, sound and colour subcarrier signals causes an intermodulation product (IP) which can be seen as a pattern on the picture corresponding to interference at f_v+1.57 MHz. The addition of a new carrier will introduce further distortion components, the most important being at f_v+0.55 MHz. Preliminary tests have shown that this distortion product is often more visible than the 1.57 MHz IP.

It is therefore necessary to quantify the impairment caused by these IPs. It is also necessary to consider whether the test signal used for objective assessment (the conventional 3-tone test) is still suitable as a test signal for the new system.

In main transmitting stations, (separate) sound transmitters are operated in a highly non-linear mode, in the interests of efficiency. This is a potential cause of distortion if the two sound carriers are to share a common amplifier because a significant IP, at 5.45 MHz, may be produced.

This Report studies the implications of the presence of the additional sound carrier on the specification of linearity performance. The use of a new test signal is considered and the subjective effect of the distortion is quantified.

2. THEORY

2.1 Generation of intermodulation products

A linear amplifier produces an output, (V_o), which is proportional to the input, (V_{in}),

$$\text{i.e. } V_o = A_1.V_{in}$$

The principle of superposition may be applied. The output signal will contain the same spectral components, in the same ratios, as the input. However, if an amplifier is non-linear, then the output signal may be described by a power series:

$$V_o = \sum A_i.(V_{in})^i, \quad i = 1 \text{ to } n$$

In this case, superposition cannot be applied. The output will contain additional spectral components (intermodulation products, or IPs) as a result of the higher order terms. Each IP will have a level which is proportional to the product of the levels of the spectral components of the original signal which contribute to it. For instance, consider third-order IPs, i.e. those resulting from the term $A_3.(V_{in})^3$. Suppose the input signal consists of three tones of amplitudes X_1, X_2, and X_3 at frequencies f_1, f_2, and f_3 respectively. In-band IPs will be generated at frequencies:

$$\begin{aligned} f_{(IP3)I} &= f_1+f_2-f_3, \\ f_{(IP3)II} &= f_1-f_2+f_3, \\ f_{(IP3)III} &= 2f_1-f_3, \\ f_{(IP3)IV} &= 2f_1-f_2 \quad \text{etc.} \end{aligned}$$

and at levels proportional[2] to:

$$\begin{aligned} V_{(IP3)I} &= (3/2).A_3.X_1.X_2.X_3, \\ V_{(IP3)II} &= (3/2).A_3.X_1.X_2.X_3, \\ V_{(IP3)III} &= (3/4).A_3.X_{12}.X_3, \\ V_{(IP3)IV} &= (3/4).A_3.X_{12}.X_2 \text{ etc, respectively}^3. \end{aligned}$$

(Other combinations will be generated at frequencies such as $f_1+f_2+f_3$ and $2f_1+f_2$, but these frequencies lie outside the immediate band around the three carriers.)

The IP levels also depend on the coefficient A3. This is a function of the amplifier.

Fifth-order (so called degenerate) products will occur at frequencies such as:

$$f_{(IP5)I} = f_1+f_1-f_1+f_2-f_3,$$
$$f_{(IP5)II} = f_1+f_2-f_2+f_2-f_3,$$
$$f_{(IP5)III} = f_1-f_2+f_3-f_3-f_3,$$
$$f_{(IP5)IV} = f_1+f_1-f_1-f_2+f_3, \quad \text{etc.}$$

Frequencies $f_{(IP5)I}$, $f_{(IP5)II}$ and $f_{(IP5)III}$ coincide with $f_{(IP3)I}$ (i.e. at $f_1+f_2-f_3$) and the levels of each of the IPs will be proportional[2] to:

$$V_{(IP5)I} = (15/4).A_5.X_1.X_1.X_1.X_2.X_3,$$
$$V_{(IP5)II} = (15/4).A_5.X_1.X_2.X_2.X_2.X_3,$$
$$V_{(IP5)III} = (15/4).A_5.X_1.X_2.X_3.X_3.X_3,$$

2.2 Intermodulation products in television signals

Most amplifiers, using conventional technology, have predominantly third-order non-linearity. Hence, third-order IPs tend to be the most significant. However, some devices, particularly those using solid-state technology, may exhibit higher-order non-linearity, even under normal operating conditions, and generate significant levels of, in particular, fifth-order IPs.

Fig. 1(a) shows the basic components of the spectrum of a conventional System I PAL television signal. Vision carrier, colour subcarrier and sound carrier are at f_v, f_{csc} and f_{s1}, respectively. Two in-band IPs will be generated by a simple, third-order, non-linearity; they are shown at 1.57 MHz and 2.856 MHz. Of these, only the IP at 1.57 MHz above the vision carrier is significant. Its level is proportional to $X_v.X_{csc}.X_{s1}$.

The other IP at 2.86 MHz, is a product of the colour subcarrier and sound carrier only. Therefore its level (which is proportional to $(X_{csc})2.X_{s1}$) is generally low.

Fig. 1(b) shows the additional IPs which may result from the addition of a second sound carrier at f_{s2}. Again, those products involving the vision carrier are the most significant. These are at ±0.55 MHz about the vision carrier frequency. In addition, if the vision carrier is amplified separately and the two sound carriers have a common amplifier then the IPs at 5.45 MHz and 7.1 MHz (in the upper adjacent channel) may be noticeable. (In this case it may be because the common sound amplifier is being operated at high efficiency.)

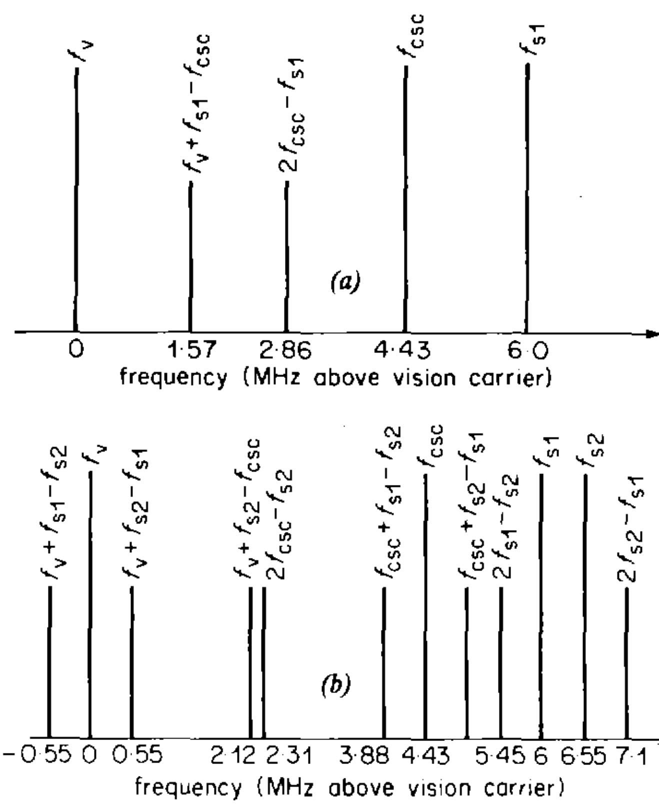


Fig. 1 - Intermodulation products before and after the introduction of the stereo sound carrier.

(a) Before.

(b) After. Showing the additional IPs resulting from the introduction of the stereo sound carrier.

This Report considers only those IPs at f_v+0.55 MHz* and f_v +5.45 MHz. However, measurement of the IP at 7.1 MHz (probably with reference to potential interference problems) may be made using the same test signal proposed for the IP at 5.45 MHz.

2.3 The most significant intermodulation products

2.3.1 The intermodulation product at f_v+1.57 MHz

This is the main IP present in a conventional television signal. It is a product of the vision carrier, the colour subcarrier and the sound carrier. It will appear as a low frequency luminance pattern. Since the sound carrier is frequency modulated, and at a constant level, the 1.57 MHz IP level varies with picture content only. Thus it will be at a maximum when the modulated colour subcarrier and the modulated vision carrier are, together, at their maximum levels. Since negative amplitude modulation is used, low luminance levels correspond to high vision carrier levels. Therefore, the 1.57 MHz IP will be highest in low luminance, saturated colours. Note that there will be no IP present in black, or dark grey areas.

* VSB filtering in receivers reduces the effective level of the IP at −0.55 MHz by at least 8 dB so it is of minor importance.

2.3.2 The intermodulation product at f_v+0.55 MHz

The IP at 0.55 MHz is a product of the vision carrier and the two sound carriers. Since only the vision carrier is amplitude modulated, the IP level varies with picture content. Again, it will be highest when the luminance level is low. Since, in this case, the IP level does not depend on the presence of colour subcarrier, it will be present in all areas of low luminance. Because of this and because of its coarser structure, it may be expected to be more visible, for any given level, than the 1.57 MHz 'sound/chroma' IP[1].

2.3.3 The intermodulation product at f_v+5.45 MHz

This IP is a product of the two sound carriers. It may reveal itself in two ways. The IP corresponds to a high luminance frequency (5.45 MHz) which will be displayed by monitors with sufficient luminance bandwidth. Alternatively, in receivers with chrominance circuits of sufficiently wide bandwidth, it will be interpreted as a chrominance signal of 1.02 MHz (this being the difference between the IP frequency and colour subcarrier frequency). Because of non-constant luminance decoding, this will appear as low spatial frequency luminance patterning, which is more visible than if it appeared simply as chrominance patterning. Low spatial frequencies are more visible than high spatial frequencies. Hence, the 1.02 MHz chrominance patterning, when it occurs, might be expected to be more noticeable than the fine luminance patterning.

2.4 Test signals

2.4.1 The present 3-tone test

In order to evaluate the linearity of an amplifier objectively, a test signal is required. The performance of the amplifier can then be defined by measuring the level of IP generated using the test signal. However, when defining a suitable specification, it is also necessary to relate the actual, worst-case (or, at least, near-worst case) IP level which can occur under operational conditions to the corresponding IP level produced by the test signal, taking into account its subjective effect. This implies that the test signal should be, in some way, representative of a real broadcast signal.

At present the '3-tone test' is used. This signal consists of tones at frequencies corresponding to the vision carrier (f_v), colour subcarrier, (f_{csc}), and sound carrier, (f_{s1}). The relative levels are shown in Fig. 2(a).

* dBp is used to indicate dB with respect to peak vision power level, during the synchronising pulse.

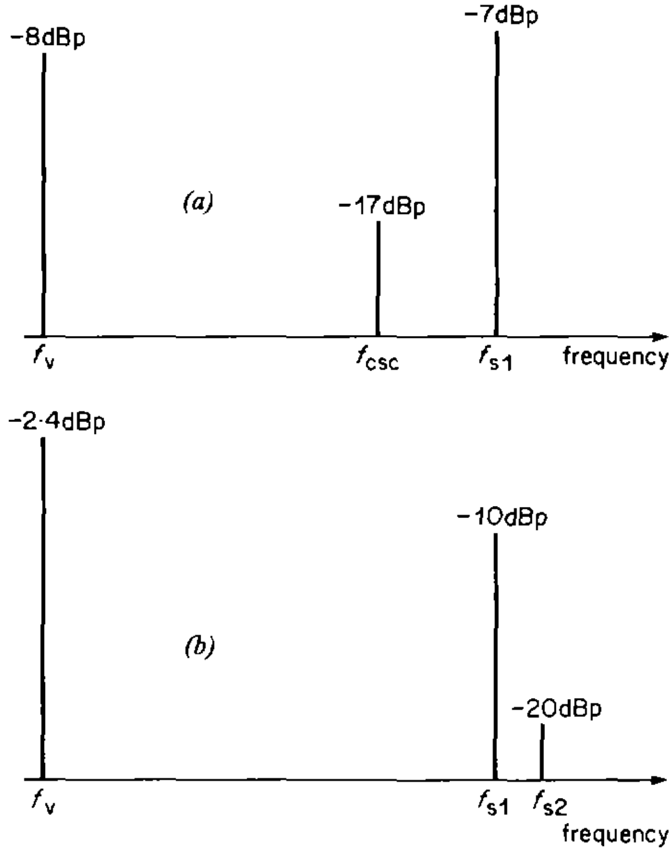


Fig. 2 - Comparison of levels of conventional and modified 3-tone test signals.

(a) Conventional. (Levels relative to peak vision power, in synchronising pulse).

(b) Modified. (Levels relative to peak vision power, in synchronising pulse).

The tone at f_v is at −8 dBp* and the tones at f_{csc} and f_{s1} are at −17 dBp and −7 dBp respectively. This test signal is fairly stringent, corresponding to a picture with full colour saturation and a mid value of luminance. In addition, the conventional 3-tone test signal also happens to have a peak power corresponding to 0 dBp.

The normal acceptance limit for a transmitter, using this test, is that the IP at 1.57 MHz should be no greater than −52 dBp. In the interests of economy, two less stringent performance specifications, Standard P and Standard Q, are applied to equipment used in relay stations serving relatively small populations, in marginal situations. (See Appendix). The specified level of the 1.57 MHz IP for Standard P transmitters is −48 dBp and for Standard Q transmitters it is −40 dBp.

2.4.2 Shortcomings of the present 3-tone test

As long as the IPs remain third order only, almost any three tones at any levels could be used for

a test signal. Knowing the IP level produced when one 3-tone signal passes through a given non-linearity it is possible to estimate 'dB-for-dB' what levels of other third-order IPs would be generated by a different 3-tone signal (See Section 2.1).

For instance, the maximum level of the 0.55 MHz IP, occurring in the active picture, is generated in near-black areas where the vision carrier level is about −2.4 dBp. The 0.55 MHz IP is a product of this carrier and the two sound carriers at −10 dBp and −20 dBp. Suppose that an amplifier, with third-order non-linearity, were found to produce a subjectively acceptable level of 0.55 MHz IP when the 1.57 MHz IP was measured at x dBp. The *actual level* of the 0.55 MHz IP would be:

$$V_{IP3} = x + 0.4 \text{ dBp}.$$

In this case, it would be quite acceptable to specify the linearity performance using the conventional test signal.

However, when higher-order non-linearities are present, this relationship will no longer apply. Take, for example, the extreme case of an amplifier with exclusively fifth-order non-linearity. Suppose that this amplifier were found to produce acceptable 0.55 MHz IPs when the 1.57 MHz was measured at x' dBp. The *actual level* of the 0.55 MHz IP would, in this case, be:

$$V_{IP5} = x' + 10.8 \text{ dBp}.$$

In a real amplifier, the non-linear law will be some unknown combination of third and fifth (and higher) orders and there would be a range of 10 dB uncertainty in any results produced with the standard test.

2.4.3 Initial proposal and signal used for the tests

In the light of the above arguments, a 'modified 3-tone test' was proposed and used for the tests. The test signal spectrum is shown in Fig. 2(b). This signal represents the limiting, worst-case, input signal for the generation of the 0.55 MHz IP: i.e. vision carrier, at black level (−2.4 dBp), and the two sound carriers at −10 dBp and −20 dBp.

An additional test is required for situations where sound and vision are to be amplified separately. This test signal would be used to measure 5.45 MHz IPs generated as a product of the two sound carriers. It comprises two signals, at frequencies corresponding to the two sound carriers and at levels of −10 dBp and −20 dBp, respectively.

3. EXPERIMENTAL WORK (FIRST STAGE)

Two sets of tests were conducted: One set of objective measurements was made on a range of different amplifiers, in order to demonstrate the variation in IP levels for amplifiers with differing non-linear characteristics. The work was intended to show that an alternative 3-tone test procedure is, in fact, necessary for assessing the performance of multiplex amplifiers in future.

A set of subjective tests was then made to determine the visibility of various levels of the new IPs, related to IP levels measured with the initially proposed new 3-tone and 2-tone tests.

3.1 Experimental equipment

A block diagram of the equipment used to generate the IPs is shown in Fig. 3. Two amplifiers were used in the equipment. Amplifier 1 carried the vision signal and both sound signals in order to produce the 0.55 MHz IP, and Amplifier 2 carried the two sound signals in order to produce the 5.45 MHz IP. The variable attenuators were used to adjust the signal levels passing through each amplifier to produce the required IPs independently and at the required levels. By suitable complementary 'ganging' of the attenuator settings, the overall gain could be kept constant, whilst varying the operating conditions of each amplifier and, hence, the levels of the IPs produced. Care was taken to ensure that the relative levels of vision and sound carriers, at the output, were maintained correctly at all times.

For the objective tests, the amplifiers under test were placed in the position of Amplifier 1 and, for the subjective tests, Amplifiers 1 and 2 were of identical types.

3.2 Objective measurements

For objective measurements, the sound and picture signal sources shown in Fig. 3 were replaced by signal generators giving tones at the required frequencies and levels for both the conventional 3-tone test and the modified 3-tone test.

3.2.1 Results of the objective measurements

Fig. 4 shows the variation of IP levels with input level for six different amplifiers. The graphs compare the level of the 0.55 MHz IP (using the modified 3-tone test) with that of the 1.57 MHz IP (using the conventional 3-tone test). Table 1 gives the 0.55 MHz IP levels at the input levels for which each amplifier just satisfied the conventional 3-tone test

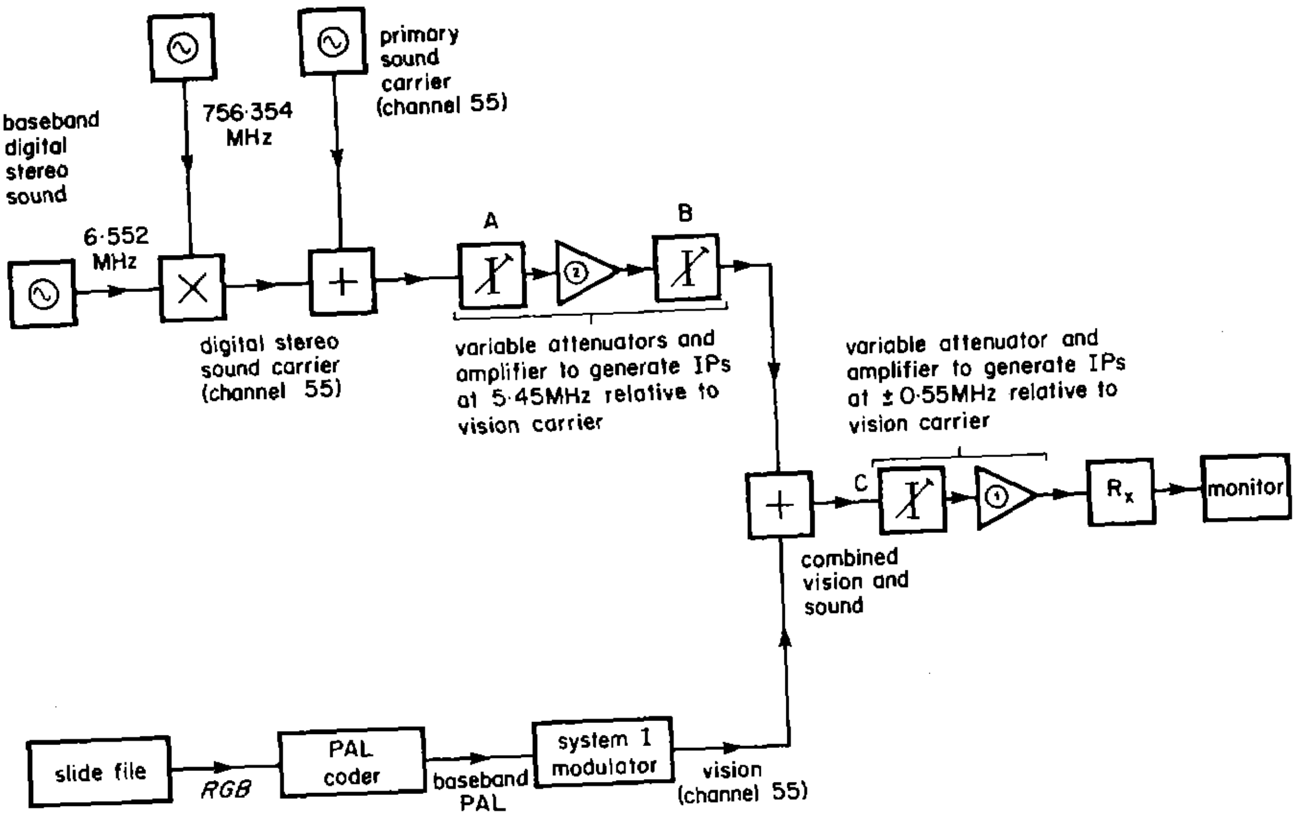


Fig. 3 - Block diagram of experimental arrangement.

(i.e. 1.57 MHz IP at −52 dBp). This corresponds to an input level of 0 dB in Fig. 4. If third-order non-linearities only were present then the 0.55 MHz IP would be −0.4 dB relative to the 1.57 MHz IP. However, both Table 2 and Fig. 4 show that, rather than having a constant difference of −0.4 dB, there is a considerable variation both with input level and between amplifiers. This indicates that it is not valid to assume that the IPs are simply third order.

Table 1

Relationship between levels of IPs measured with the experimental 3-tone test and those measured with the conventional 3-tone test.*

Amplifier	IP level (dBp)	IP level relative to 1.57 MHz IP† (at −52 dBp)
1	−47.7	4.1
2	−48.6	3.6
3	−49.1	2.8
4	−47.2	4.7
5	−42.5	9.5
6	−51.8	0.2

* In this table, the input signal is the modified 3-tone test (with vision carrier at −2.4 dBp) at an operating level for which each amplifier just satisfies the conventional 3-tone test.

† This is the 1.57 MHz IP generated by the conventional 3-tone test.

3.3 Subjective tests

For subjective measurements, the signal sources were as shown in Fig. 3. The pictures used for the tests came from a digital Slide File[4]. Three slides were used: 'Test Card G', EBU Test Slide 'Formal Pond' and 'Atoms'. The slide 'Atoms' was included as it is representative of many electronically generated pictures which are commonly transmitted. The vertical grey sawtooth in 'Atoms' is particularly sensitive to non-linear effects.

The baseband *RGB* signal was first coded as a PAL signal and then modulated onto a carrier at UHF Channel 55. The digital sound signal, at f_v +6.55 MHz was added to the primary sound carrier which was modulated by an audio frequency tone.

The viewing conditions were as recommended in CCIR Rec 500-2. Two groups of fifteen observers were asked to grade the pictures according to the CCIR 5-point impairment scale (defined in Table 2). Observations were also made using two other displays: one was a domestic receiver with RGB input and the other was a professional monitor with relatively narrow-band chrominance circuits.

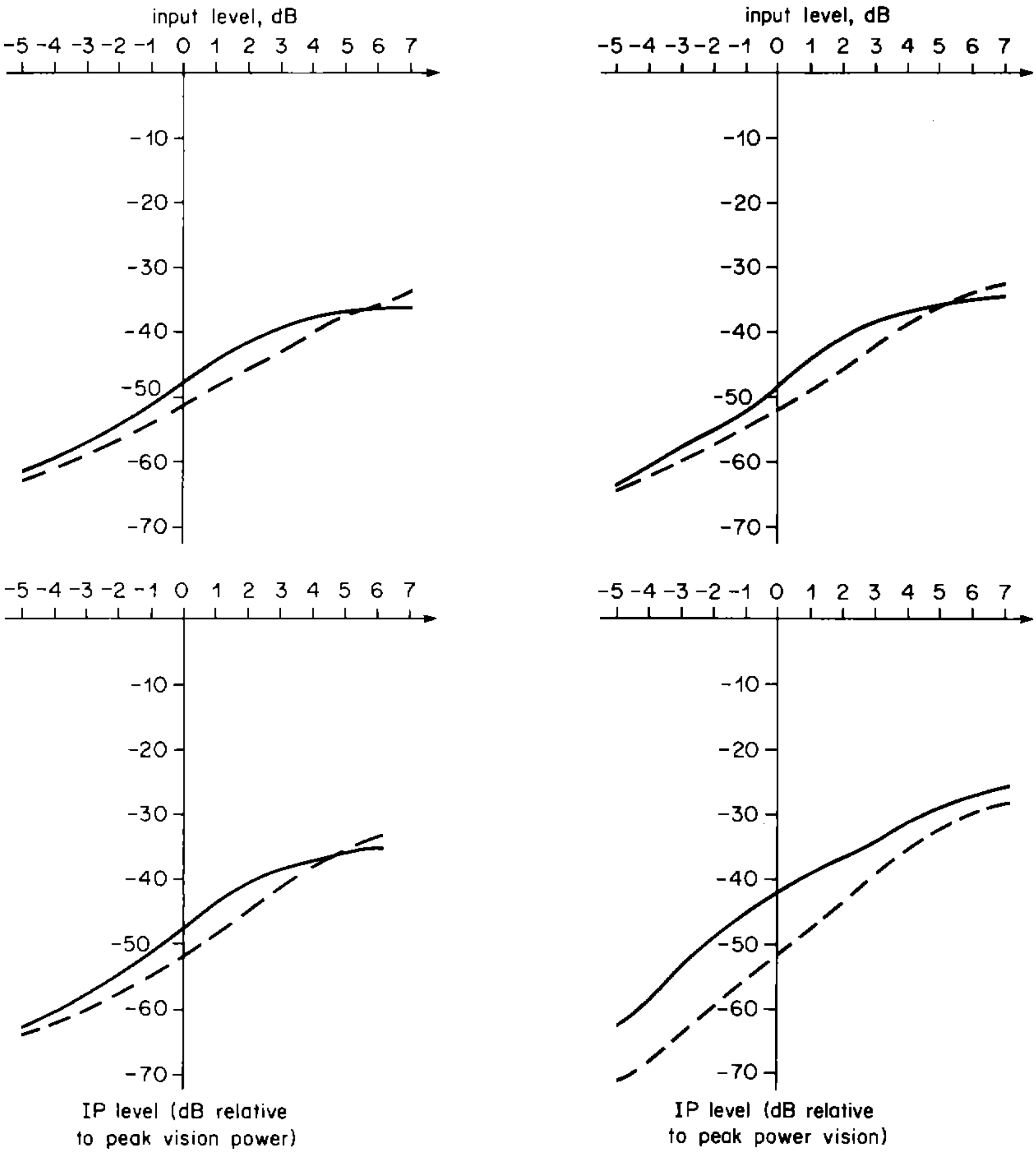
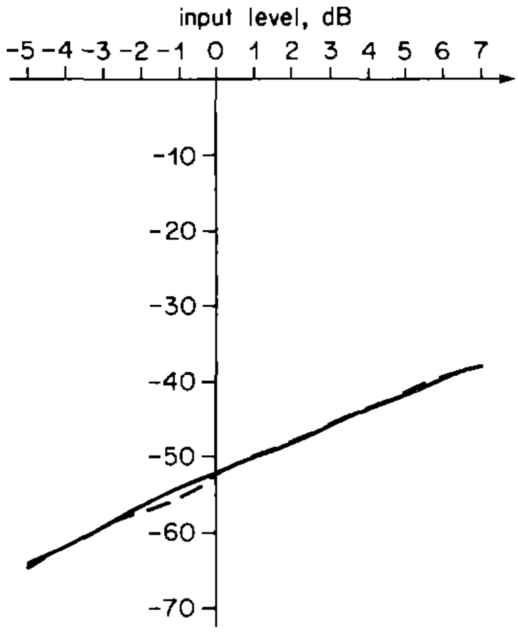


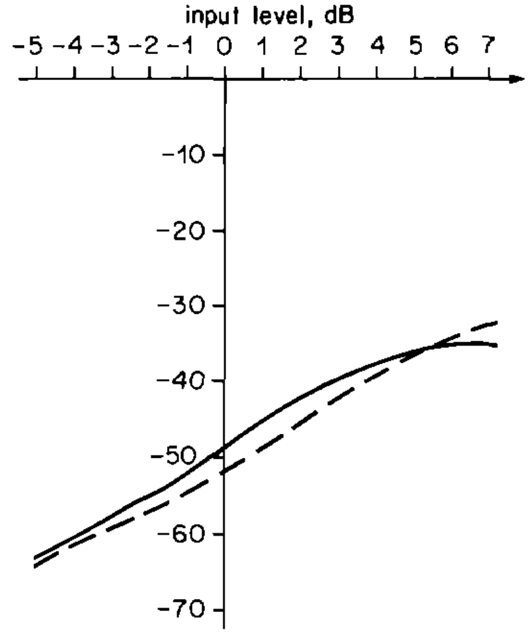
Fig. 4 - Variation of IP levels for six different amplifiers.

——— *Level of 1.57 MHz IP using the conventional 3-tone test.* — — — *Level of 0.55 MHz IP using the experimental 3-tone test.*

Table 2
The CCIR 5-point Impairment Scale

Grade	Impairment
5	Imperceptible
4	Perceptible, but not annoying
3	Visible, slightly annoying
2	Annoying
1	Very annoying





3.3.1 Results of the subjective tests

Figs. 5(a), 5(b) and 5(c) show the relationship between subjective impairment and IP level. Fig. 5(d) shows the rate of change of subjective impairment with input level. (As in Fig. 4, 0 dB corresponds to an input level at which the amplifier just satisfied the conventional 3-tone test (−52 dB) condition).

Fig. 6 contains photographs of examples of both impairments to each of the three test pictures. Figs. 6(a), 6(c) and 6(e) show 0.55 MHz IPs, measured at a level of 40 dBp (using the proposed test signal). Figs. 6(b), 6(d) and 6(f) show 5.45 MHz IPs at a level of 30 dBp.

The levels of patterning in the photographs were chosen to be high enough to make the impairments obvious. The photographs demonstrate the essential qualitative difference between the two types of impairment.

Both IPs are particularly visible on the grey vertical sawtooth background in 'Atoms'. The impairments are, more or less what might be expected, appearing as almost noise-like patterns in both coloured and grey areas of the picture. This contrasts with the well-known 1.57 MHz sound/chroma IP, which can have a very well defined, regular, pattern when the FM carrier is unmodulated. These patterns can be either stationary or moving. The 0.55 MHz IP appears as a coarse luminance pattern while the 5.45 MHz IP appears as a slightly coarser coloured pattern.

4. EXPERIMENTAL WORK (SECOND STAGE)

4.1 The need for a further modification to the test signal

Consultation with other BBC Engineering Departments revealed various objections to the use of a test signal with a vision carrier level as high as −2.4 dBp.

In practical terms it is difficult to set up or read such a level with a spectrum analyser and a 'round figure' would be much more convenient, both in the laboratory and in the field. Also, the use of a worst-possible-case carrier level in an equipment acceptance test would, almost certainly, lead to unnecessarily high costs for pre-corrected solid-state amplifiers due to over-specification. There was also an objection that cross-modulation in some transmitters would make control of the three carrier levels interactive, thus making it difficult to conduct the test.

The arguments discussed in Section 2.4.2, demonstrate that an accurate model of a near-worst-case real transmitted signal is essential in order to reveal any possible non-linear effects. It was considered that, to reduce the vision carrier level significantly would defeat the object of the exercise but that a small decrease might ease some of the objections.

A reduction to −3 dBp would satisfy the requirement for a 'round figure' and go some way to

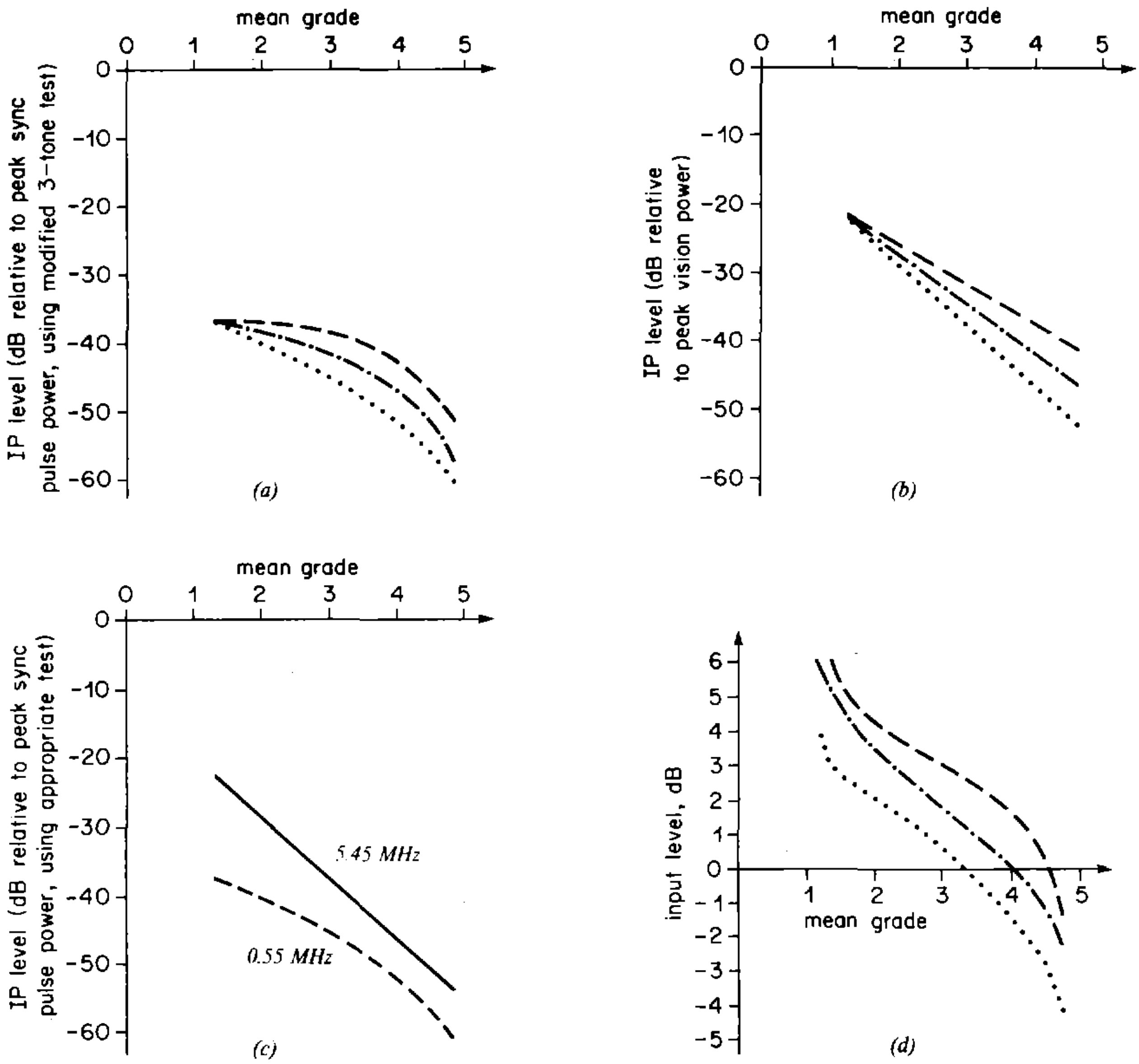


Fig. 5 - Variation of subjective impairment with IP level (a to c) and input level (d).

— — — Test Card G
—·— 'Formal Pond'
······ 'Atoms'

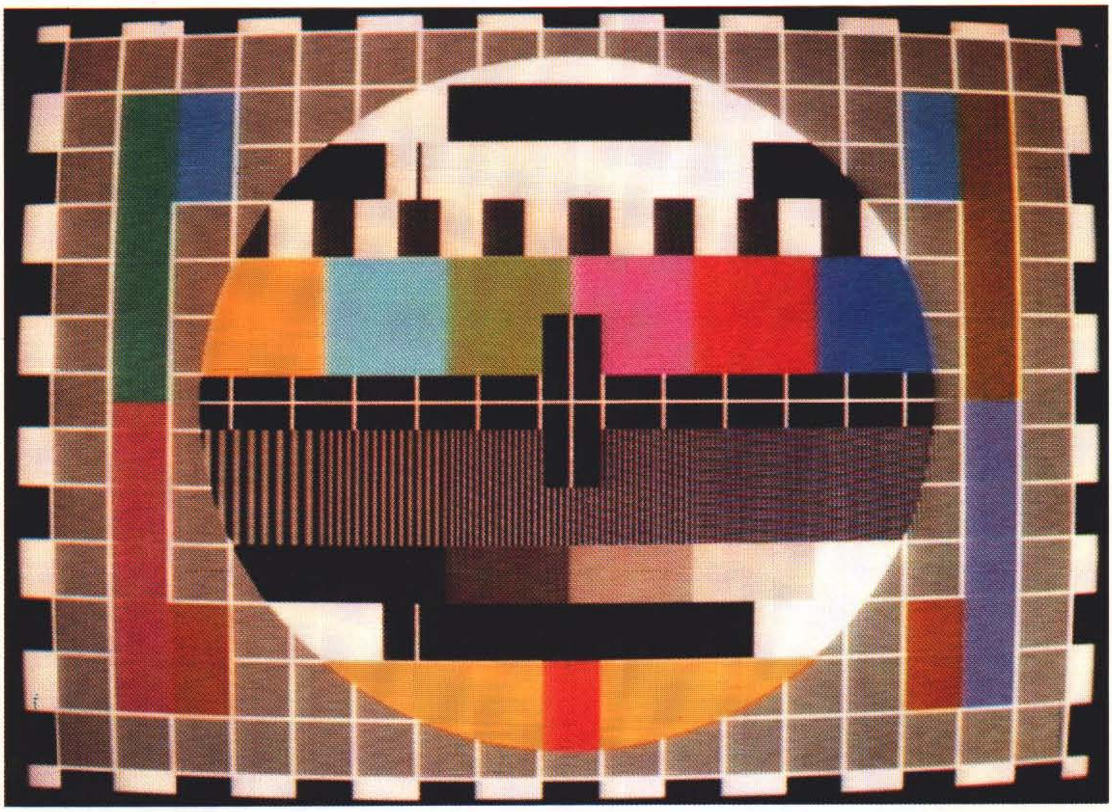
(a) 0.55 MHz IP (b) 5.45 MHz IP
(c) 5.45 MHz and 0.55 MHz IPs for 'Atoms'
(d) Variation of subjective impairment with input level

reduce the effects of operating so near the limit of the amplifier operating range.

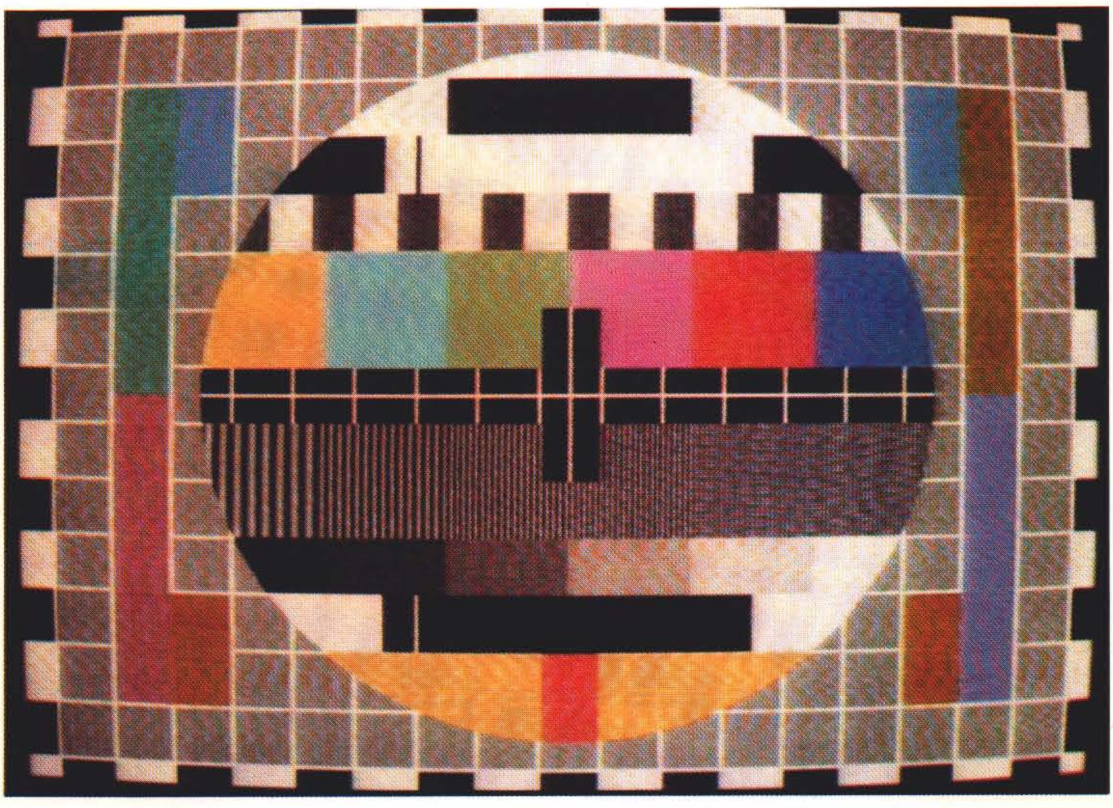
4.2 Experiments using the modified test signal

There was no time to re-run all the tests with this modified value for vision carrier so a short set of tests was made, using identical equipment, to find the amount by which the specification should be modified as a result of a change of vision carrier level to −3 dB. Fig. 7 shows how the IP level changed, for a range of impairment conditions which included 'Just Perceptible', Standard P and Standard Q. The graph shows the difference, as a function of the level of the 0.55 MHz IP, measured with a vision level of −2.4 dB. For low levels, the reduction is near 0.6 dB, which is what would be expected from a simple third-order non-linearity. As the IP increases in level, the reduction is in the region of 1.2 dB, demonstrating the presence of high-order non-linearity.

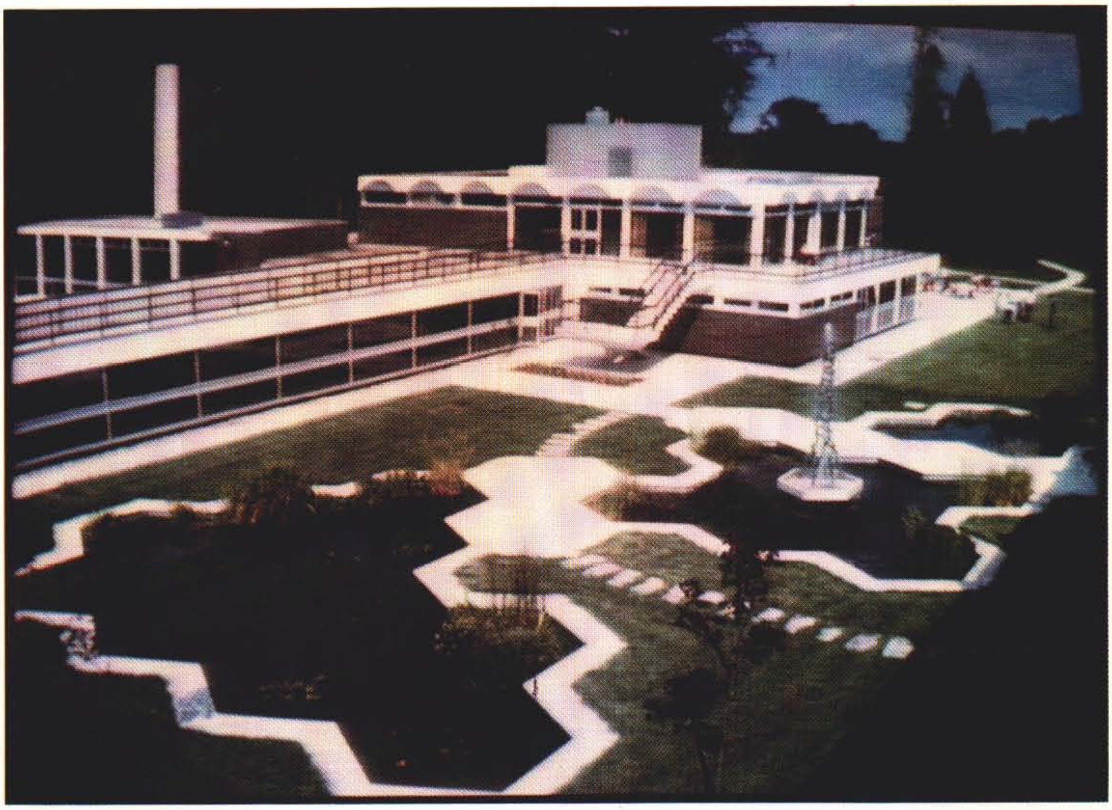
Fig. 6 - Effect of IPs on three test pictures.



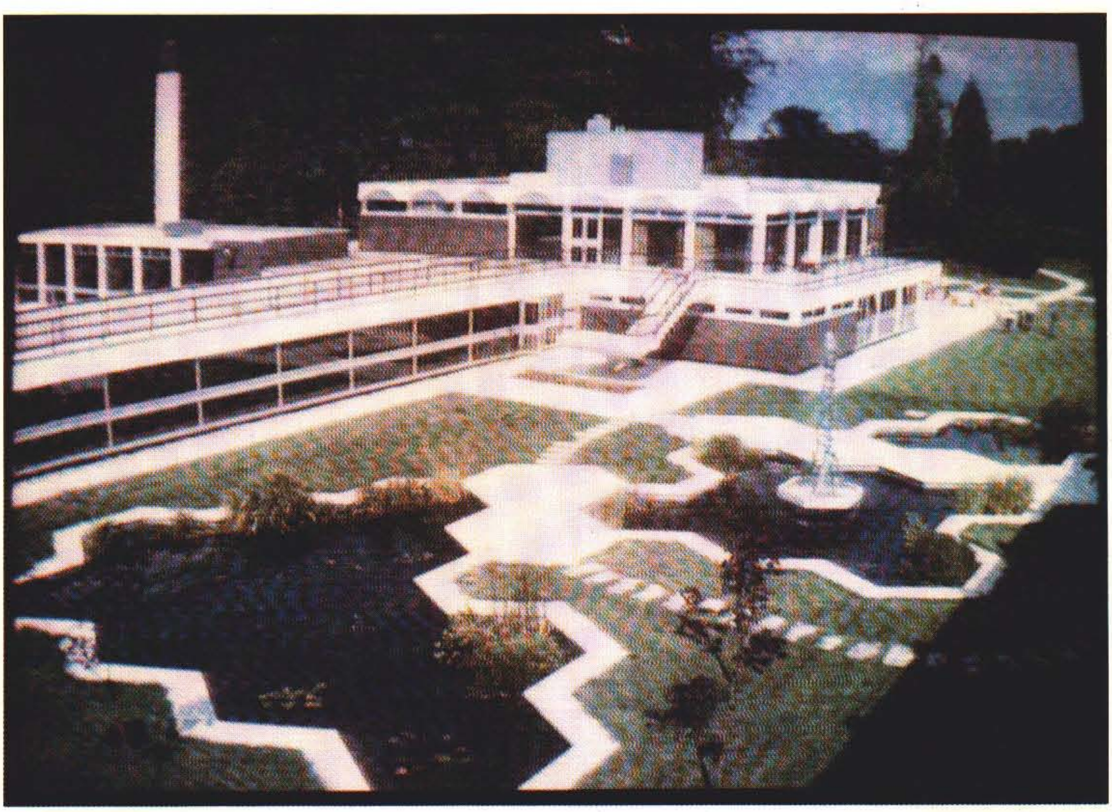
(a) Test Card G with IP at 0.55 MHz.



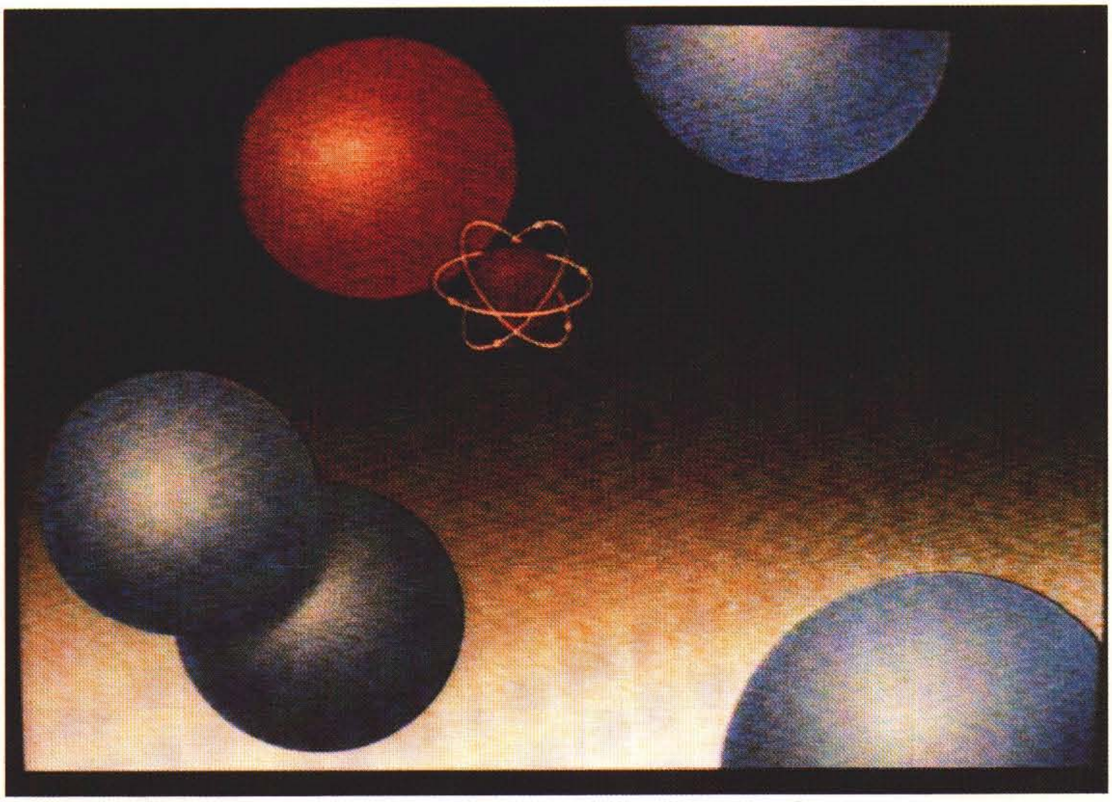
(b) Test Card G with IP at 5.45 MHz.



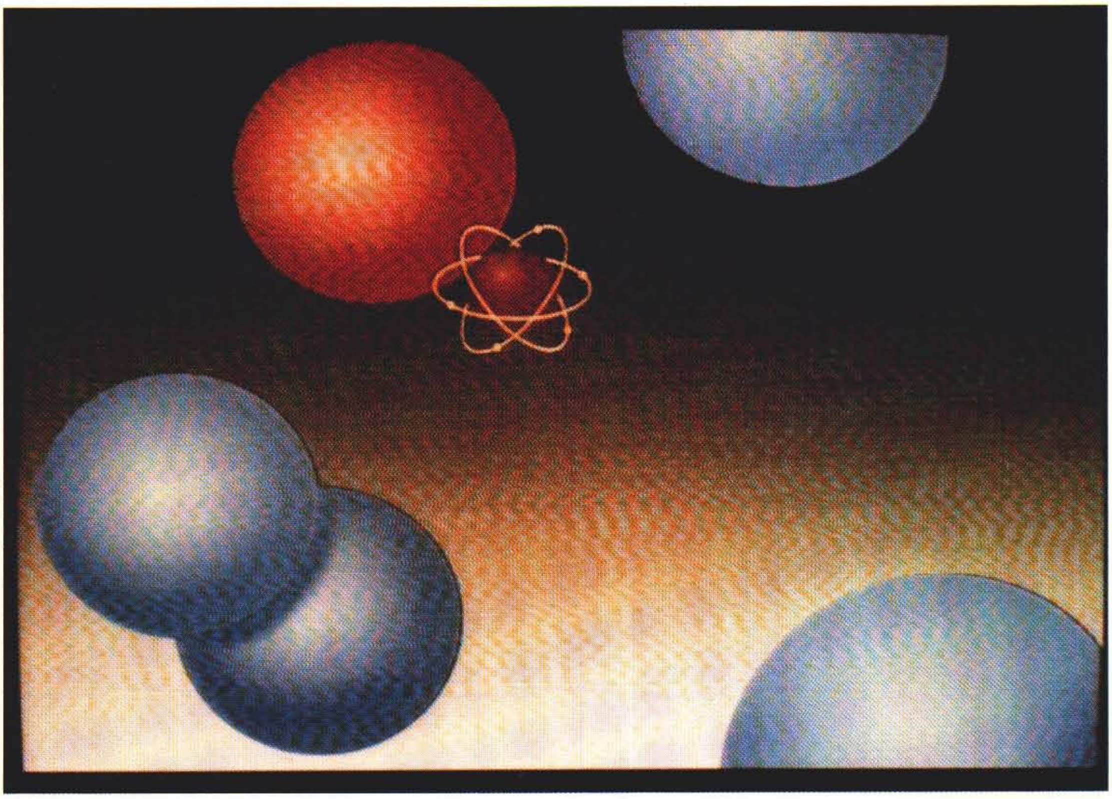
(c) 'Formal Pond' with IP at 0.55 MHz.



(d) 'Formal Pond' with IP at 5.45 MHz.



(e) 'Atoms' with IP at 0.55 MHz.



(f) 'Atoms' with IP at 5.45 MHz.

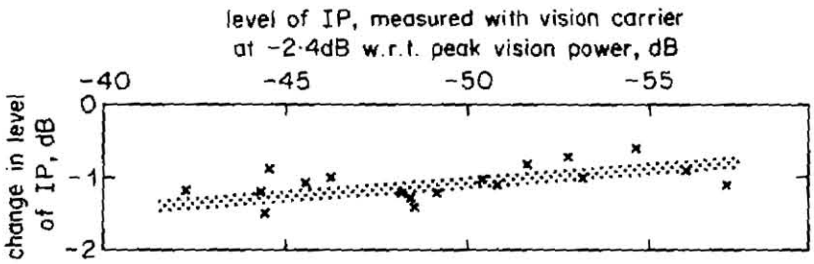


Fig. 7 - Reduction in the level of IP at f_v+0.55 MHz as a result of reducing the level of the tone at f_v from −2.4 dBp to −3 dBp.

5. DISCUSSION OF RESULTS

These investigations were made in two stages: the results of the first stage of the work all relate to the initial test signal specification; the results of the second stage of the work can be used to arrive at a performance specification, using a modified, more practicable test signal.

5.1 First stage results

Fig. 5(a) and 5(b) show that, with sensitive picture material, the impairment level is 'Just perceptible' (Grade 4.5) when the levels of the IPs, at 0.55 MHz and 5.45 MHz are −56 dBp and −52 dBp respectively. (These figures refer to measured values, obtained using the initially-proposed 3-tone test and additional 2-tone test respectively). For Standard P* (picture Grade 3.8) the corresponding values are −50.5 dBp and −46 dBp and for Standard Q (picture Grade 3) these values become −46 dBp and −38 dBp.

These results suggest that it may be necessary to de-rate some amplifiers as a consequence of introducing the stereo sound carrier. The objective results described in Section 3.2.1. indicate that the necessary degree of de-rating is likely to vary between amplifiers.

Finally it should be noted that these recommended levels have been determined by viewing the pictures on a monitor with fairly high bandwidth chrominance circuits. The visibility of the 5.45 MHz IP as low-frequency coloured patterning can vary significantly with the bandwidth of the chrominance circuits. The monitor used gave particularly visible coloured patterning compared with observations made on two monitors with low-bandwidth chrominance circuits. On the latter two, an HF luminance pattern predominated. However no formal tests, using different monitors, were carried out.

5.2 Second stage results

A level of −3 dBp, for the tone at f_v may be substituted in the specification for a 3-tone test signal. It represents a more practical value to measure and also a slightly less stringent test condition. When this reduced level is used, then the measured level of IP corresponding to a given level of impairment is reduced by the amount shown in the graph in Fig. 7. The values on the graph have been used to modify the first stage results in arriving at the proposed specification in the following section.

6. PROPOSED 3-TONE TEST FOR NICAM 728 AND REQUIRED PERFORMANCE SPECIFICATION

A new 3-tone test signal has been proposed for measuring IP performance of UHF television transmitting amplifiers, required to carry a NICAM 728 signal. The test signal should comprise three tones, at frequencies f_v, f_{s1} and f_{s2} and at levels of −3 dBp, −10 dBp and −20 dBp, respectively. (The levels to be measured at the output of the amplifier.) The signal represents the limiting, near-worst-case, for the generation of a 0.55 MHz IP: i.e. vision carrier, at near black level and the two sound carriers at their normal specified level.

In addition, the tone at f_{s2} should be frequency modulated at a slow rate with a peak deviation of one quarter of the bit rate (180 kHz). The frequency sweep rate should be sufficiently low to ensure that all the IPs appear on a spectrum analyser trace and are not missed due to strobing of the two sweep rates. This should enable detection of any IPs which a precorrector, set up to eliminate single-tone IPs, might not cancel.

An additional test is required for situations where sound and vision are to be amplified separately. This test signal would be used to measure 5.45 MHz IPs generated as a result of the two sound carriers. It comprises two signals, at frequencies f_{s1} and f_{s2}, at levels of −10 dBp and −20 dBp, respectively. Again, the tone corresponding to the stereo sound carrier should be frequency modulated.

Table 3 shows the proposed specification for the acceptable levels of IPs, generated using the proposed three- and two-tone tests. The values of

* See Appendix for definitions and discussion of Standards P and Q.

appropriate level for the 0.55 MHz IP are the result of combining the results of the subjective test (using results for the 'Atoms' picture in Fig. 5(b)) with the information in Fig. 7 (adjustment for the modified vision carrier level).

NOTE: The level of the 5.45 MHz IP will also depend upon any filtering used in the sound/vision combiner, which should be taken into account in assessing performance.

Table 3
Specification of permissible IP levels.

Standard	IP level (dBp)	
	0.55 MHz*	5.45 MHz†
Just Perceptible	−57	−52
P	−53	−46
Q	−47	−38

* Using modified 3-tone test with −3 dBp vision carrier level and sound carriers at −10 dBp and −20 dBp.

† Using new 2-tone test with sound carriers only.

7. CONCLUSIONS

The introduction of the stereo sound carrier to the terrestrial transmitter network may lead to increased levels of impairment due to intermodulation distortion. This takes the form of new intermodulation products at frequencies of about 0.55 MHz and 5.45 MHz above the vision carrier frequency. These are visible as different forms of patterning on the displayed picture, especially in dark grey areas of the picture.

It has been demonstrated that the existing 3-tone test does not predict, accurately enough, the level at which these IPs are generated. This is because fifth-, and higher-order, non-linearities have a significant effect in relevant areas of the picture.

Two new test signals have been proposed: a new 3-tone test, for common vision and sound amplifiers and a 2-tone test for amplifiers carrying only the two sound signals. These are recommended for specifying UHF amplifiers for the new service.

A series of subjective tests has been held to determine the acceptable levels of new IPs generated as a result of the addition of the stereo sound carrier. The results indicate that, for just perceptible impairment, the maximum levels of the 0.55 MHz IP and 5.45 MHz IP (when using the proposed test signals) should be at −56 dBp and −52 dBp respectively.

As a result, it may be necessary to de-rate some UHF amplifiers in order to ensure that the IPs are at an acceptable level.

8. REFERENCES

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APPENDIX

Standards P and Q

When setting the specification for performance of main transmitters and relay stations, a range of standards is appropriate.

At main stations, in view of the fact that a large number of viewers are served, it is important that the transmission be maintained at a high quality. Transmission impairments are usually specified to be not worse than 'Just Perceptible'. This corresponds to Grade 4.5 on the CCIR 5-point Impairment Scale. Exceptions to this rule would only be tolerated during maintenance periods or when, for example, there is a fault and the transmitter is being operated in a reserve mode. Under these, temporary, conditions, additional impairments may be tolerated. For example, a worse IP performance may be accepted in order to obtain sufficient output power to serve as wide an area as possible, under the fault condition.

At relay stations, for economic reasons, there must be a compromise between the size of population served and the quality of service provided. In 1974, a joint group from the BBC and IBA studied the problem and agreed on two standards which were to be applied to relay stations in certain marginal situations where it is considered uneconomic to provide a service of the highest quality.

Standard 'P' was chosen to be the standard applicable to stations with a net coverage* of more than 2000 people.

Standard 'Q' was chosen as the standard applicable to the last station in any chain where the net coverage is less than 2000 people.

A wide range of impairments was covered in the study, including the effects of noise and interference, the sound/vision ratio and the effects of linear and non-linear distortions. The limiting values were chosen, for each type of impairment, bearing in mind such factors as cost and stability of equipment. For intermodulation distortion, the limiting impairments were:

Standard 'P'

50% of observers to consider the impairment 'Just Perceptible' and 50% to consider the impairment 'Definitely perceptible but not disturbing'.

Standard 'Q'

The impairment to be rated 'Somewhat objectionable'.

These impairments correspond to Grades 2.5 and 4, respectively, on the old CCIR 6-point impairment scale. On the new CCIR 5-point scale the corresponding grades, using linear translation from one scale to the other, are:

Standard 'P' Grade 3.8

Standard 'Q' Grade 3

* This is to include the service areas of any relay stations which are fed by the relay station in question.

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